RESEARCH DEPARTMENT

The design and construction of a free field sound measurement room

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RESEARCH DEPARTMENT

THE DESIGN AND CONSTRUCTION OF A FREE FIELD SOUND MEASUREMENT ROOM

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SUMMARY

A second free field sound measurement room has been built at Kingswood Warren to increase the facilities for research into fundamental acoustical problems, for subjective tests and for the testing of equipment.

This report describes the construction of the room, which has a working space of 20 ft 3 in. × 16 ft 3 in. × 10 ft 3 in. high (6·17 m × 4·95 m × 3·12 m). The report also deals with some of the design problems that were encountered, and the solutions to these problems.

The free field sound measurement room forms only part of the building described, and special precautions were taken in the design to overcome the transmission of sound to the room from neighbouring rooms and extraneous sources.

The room was designed to a specification drawn up by the Electro-Acoustics Group and other reports deal with the technical requirements and acoustic properties.[1,2]

1. INTRODUCTION

The need for a free field sound measurement room* within the BBC arises from the necessity to carry out research into fundamental acoustical problems, into sound insulation studies, and for subjective tests as for instance in investigations on stereophony and the testing of equipment such as loudspeakers and microphones. The work to be undertaken had of course determined the design parameters of the room and these were specified by the Electro-Acoustics Group.

The specification of this building resulted from close liaison between Electro-Acoustics Group, the Department's Technical Services, and Building Department. Such liaison played an important part in getting a successful design of building. The interior of the free field room was, however, designed, built and erected by Research Department staff.

* The term 'free field room' will be used throughout the remainder of this report, except in headings or sub-headings.

A similar but smaller room has been in existence since 1950 with a working space of approximately 16 ft × 10 ft 6 in. × 6 ft 6 in. high (4·9 m × 3·2 m × 2 m) but this was proving inadequate both for size and performance for some applications. The volume of work had also become more than could be accommodated in one free field room. Advantage was taken in designing the new room to improve on the existing design and to introduce modern materials and manufacturing techniques.

2. GENERAL BUILDING DETAILS

The new building comprises a free field room, an apparatus room, a store, an attic and basement. The layout is shown in Fig. 1. In a structural sense, the free

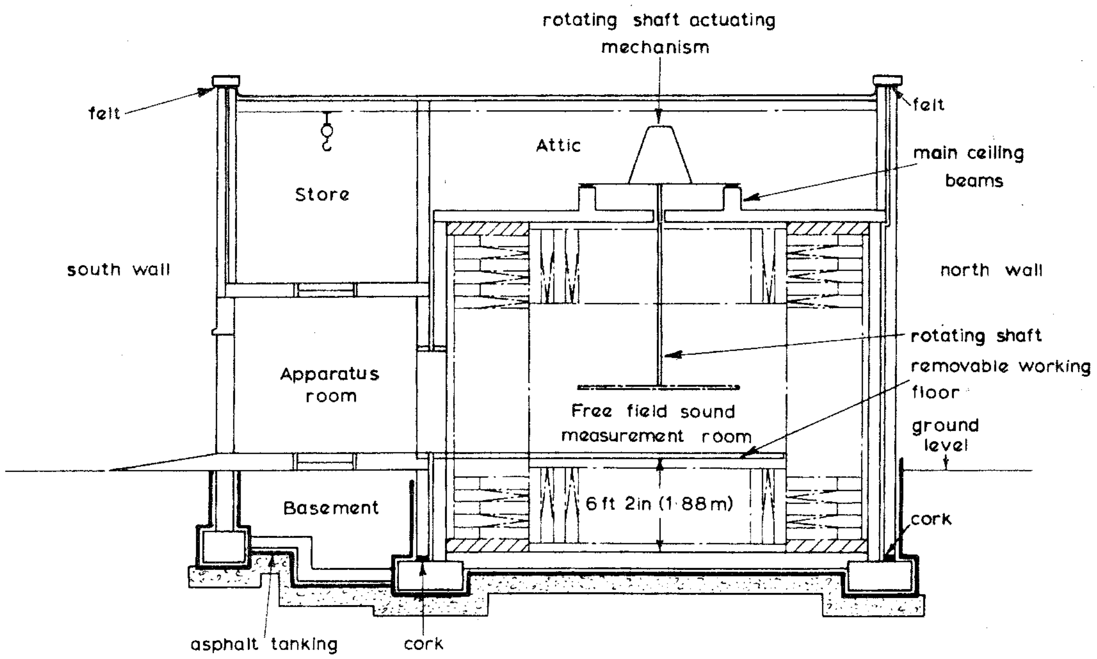


Fig. 1 - Cross section of building showing general details

field room is a separate box, within the outer four walls of the building, with the floor level of the box being 6 ft (1·83 m) below ground level. The inside of this 'separate box' is completely covered by sound absorbing wedges, giving a working space of 20 ft 3 in. × 16 ft 3 in. × 10 ft 3 in. high (6·17 m × 4·95 m × 3·12 m). The whole of the building below ground level was tanked with a 1 in. (25·4 mm) thickness of asphalt to keep to a minimum dampness and the transmission of ground-borne sounds to the structure.

Further measures have been taken in the design to ensure the minimum of sound transmissions to the free field room from the surrounding structure. There is a 3 in. (76 mm) cavity between the walls of the room and walls immediately adjacent, and where wall-ties were used, they were of a type consisting of a rubber block into which two metal strips were bonded, thus ensuring no through metal path from wall to wall. Also, cork strips were placed between the foundations and the outer walls, and felt strips were placed under the coping at the top of the walls.

By means of these precautions, there is no structural path between the free field room and the remainder of the building, other than through some form of sound or vibration damping medium. It was realized, however, that these precautions would be nullified if mortar were to fall into the cavities during the construction of the walls, and steps were taken to avoid this happening.

The ceiling of the free field room is constructed in 8 in. (203 mm) reinforced concrete, to provide a heavy mass, thus reducing to a minimum any possibility of the transfer of noise into the free field room from above. Further attenuation of overhead noise, such as that developed by aircraft, is obtained by virtue of the attic, which also provides a space to house the actuating mechanism required to rotate equipment undergoing test in the free field room.

Cast into the ceiling are seventeen bitumastic tubes. Into nine of these, are fitted 3¼ in. (83 mm) diameter steel guide tubes, to provide passage for lighting fittings through the sound absorbing treatment on the ceiling. (These guide tubes can be seen in Fig. 17.) The remaining eight holes are fitted with 2¾ in. (70 mm) diameter steel guide tubes for the shaft of the actuating mechanism, thus providing eight possible places through which the shaft can protrude into the free field room. These holes are referred to later.

An aluminium ladder provides access to the attic space, and a 5 cwt (25·4 kg) hoist enables equipment to be lifted into the attic or lowered to the basement through trapdoors.

During the construction of the brickwork, every precaution was taken to see that the dimensions, and squareness of the building were maintained to close limits to ensure that no difficulties would arise when the prefabricated internal treatment of the free field room was fitted into place.

3. INTERNAL TREATMENT OF THE FREE FIELD SOUND MEASUREMENT ROOM

3.1. Sound Absorbers[1]

The starting point in the design of the treatment for the inside of the free field room was the estimate that the treatment would need to be nominally 5 ft (1·52 m) in depth to enable the room to give the desired performance figures laid down in the specification, this depth of treatment including a 6 in. (150 mm) air space between the absorbing material and the walls. It had also been ascertained that the most effective method of providing the internal treatment was in the form of wedges, and Fig. 2

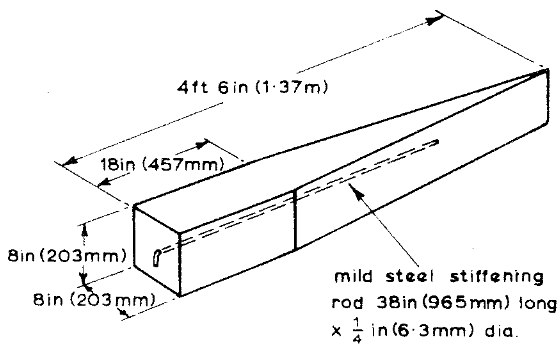


Fig. 2

Sound absorbing wedge and stiffening rod as used for wall and ceiling treatment

shows the design of the wedges eventually used. In the preliminary planning it was realized that the likely material would be polyurethane, and when a suitable material was found, tests indicated that the optimum air gap should be 4½ in. (114 mm) rather than 6 in. (150 mm), this reducing the depth of treatment to 4 ft 10½ in. (1·48 m). The manufacturing specification of the polyurethane was, at that time, much broader than was essential for materials to be used in the room under review. Arrangements were made with the manufacturer for a sample to be tested by Research Department on each occasion that the manufacturer was processing a batch of the particular foam. By this selection process it became possible to utilize the polyurethane foam that satisfied the very tight specification to produce the 5192 wedges needed.

Having chosen the size of the wedges, and selected the material from which they should be made, various methods of supporting them were considered, according to whether they were to be located on the walls, the ceiling or the floor, and bearing in mind the need to provide services in the room such as heating and electricity. After experiments with a test rig simulating a section of acoustically treated wall, the final design adopted consisted of a metal framework, 16 in. (406 mm) deep, made up of wire grids having the wires spaced to form 8 in. (203 mm) square holes into which the wedges were to be inserted. Although the 16 in. (406 mm) depth was maintained for all frameworks, the other dimensions varied according to the location in which they were to be used.

Where wedges were to be used for wall treatment, experiments showed that steel rods, ¼ in. diameter × 38 in. long (6·3 mm diameter × 965 mm) inserted into the bases of the wedges gave adequate increase in stiffness to the wedges when they were used in the cantilever position, leaving only the tips of the wedges to be additionally supported.

The addition of the rods (Fig. 2) also improved the acoustic performance of the wedges due to the increase in the total mass, and wedges suspended from the ceiling were also provided with rods for this reason. A different type of rod was designed for the wedges on the floor, and these are described later (see Section 3.4.1).

3.2. Wall Treatment

Most of the details of the wall treatment in the free field room are shown in Fig. 3. The east and west walls are completely covered with wedges, except for an 8 in. (203 mm) strip at the floor, ceiling and on each side. This is shown in the plan view of Fig. 3. The wedges on these two walls cover two vertical areas of the north and south walls, but the remaining areas are treated with wedges as for the east and west walls except for the door area in the south wall.

The frameworks holding the wedges are supported on light angle-iron trestles, placed along the foot of each wall. Any inaccuracies in the level of the concrete floor were taken into account when building these trestles, to ensure that the surface on which the framework rested was level around the whole room.

It will be appreciated that the framework covering a wall would be too large to be prefabricated in one piece in the Workshops and then taken into the room. In most cases, therefore, the framework was made up of sections which were five squares wide (40 in., 1·02 m) and fourteen squares high (112 in., 2·85 m), the frames being wired together in situ and tied to the walls by hooked brackets which are in turn screwed to wooden battens mounted horizontally on the walls, at 32 in. (814 mm) centres.

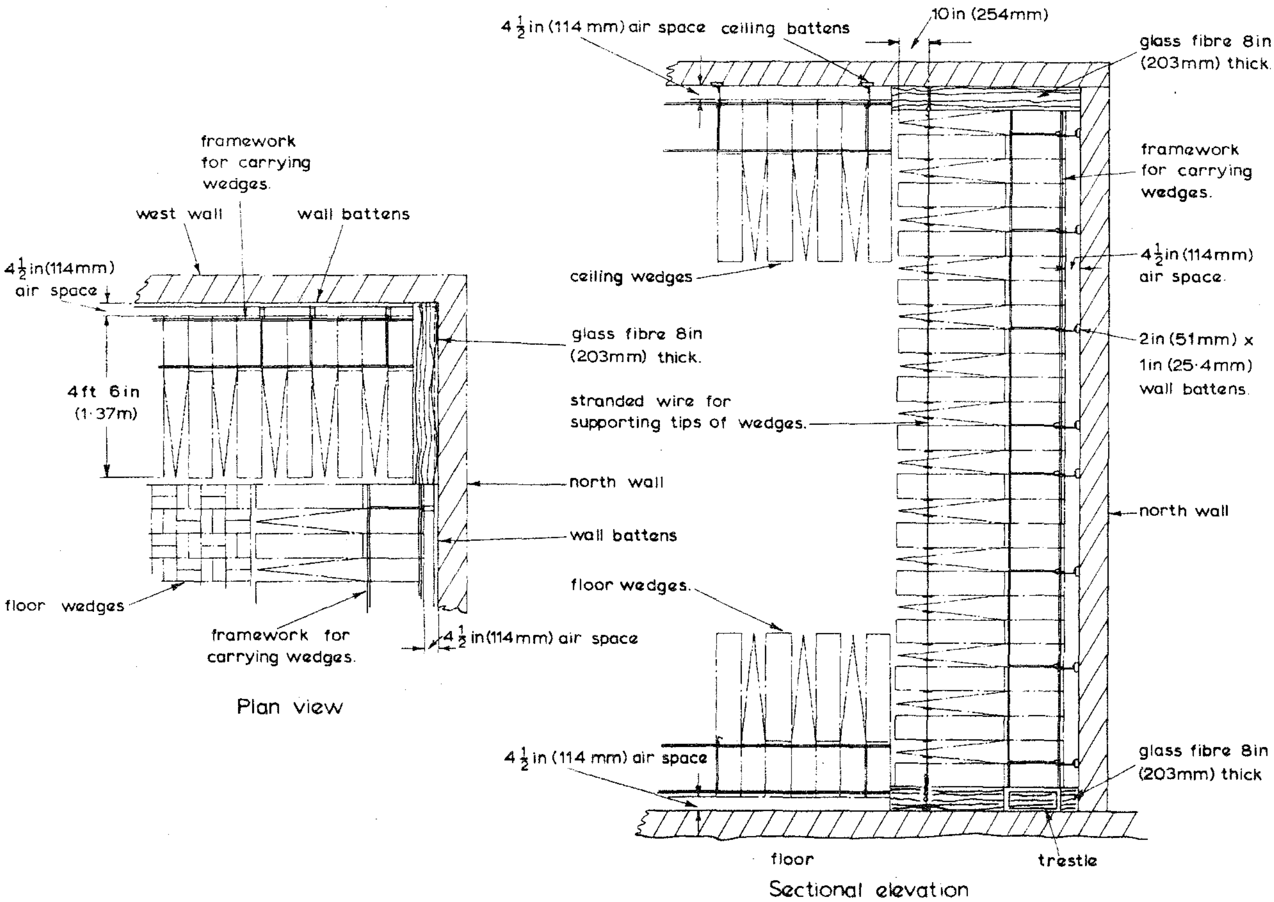


Fig. 3 - Details of sound absorbing treatment

The 8 in. (203 mm) gap around the wall treatment, and the areas above and below the banks of wedges are filled with glass fibre, that below the wedge bank being placed inside the trestles thus avoiding the possibility of the glass fibre being crushed. The glass fibre above the wedges is held in place with lacing twine, criss-crossed between drop brackets mounted via angle strips screwed to 'cast in' ceiling battens.

The glass fibre was necessary since between the wedges on the walls and those on the ceiling and floor there exist paths which would allow sound to have access to the ceiling and floor. This also applies where the wall wedges on the east and west walls meet those of the north and south walls. By placing the glass fibre as shown in Fig. 3, any sound travelling along these paths would be effectively absorbed by the glass fibre.

Although the description of the wall treatment just given first deals with the wedges and framework, it was realised that to make the task easier when the erecting procedure was being considered, it was preferable to fit all the glass fibre into place before the framework and wedges.

As previously mentioned, whilst the steel rods in the wedges give stiffness for some distance from the back of the wedges it was found that their tapered ends drooped too much. Furthermore, due to the softness of the wedge material, the wire from which the cages were made (¼ in. diameter, 6·3 mm) impressed itself deeply into the wedges, causing them to cant downwards. The latter distortion was corrected by increasing the area supporting the wedges with expanded metal shelves extending from the back to the front of the cages, the shelves being clipped into position. To support the tapered end, stranded wires were passed between each vertical row of wedges, these wires being secured to ceiling battens at the top, and tensioned at floor level, with expanded metal strips placed between these wires, one strip under each wedge 10 in. (254 mm) from the tip. The strips were located on the wires by small springs, each spring being correctly positioned by a small deposit of solder. Fig. 3 shows the fixing arrangements of the stranded wires at ceiling and floor level. Fig. 4 shows the arrangement of the wires, shelves and metal strips.

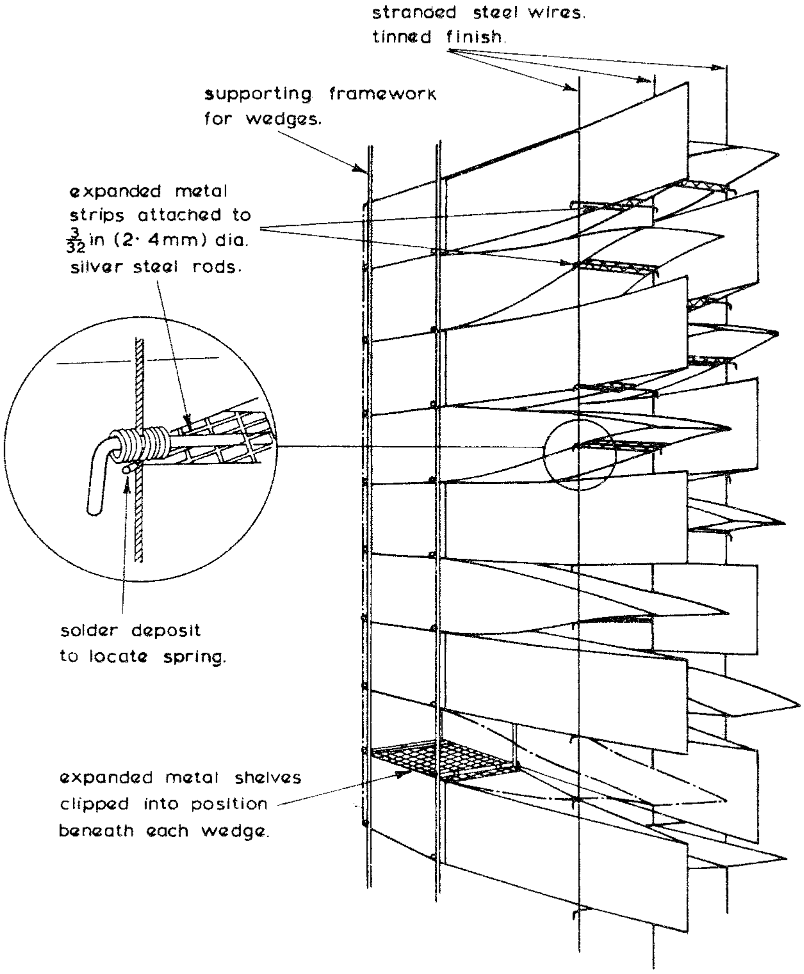


Fig. 4 - Details of supports for tapered ends of wedges

3.3. Ceiling Treatment

Due to the wall wedges extending into the room by 4 ft 10½ in. (1·48 m), the ceiling area to be covered with wedges was reduced to 20 ft 3 in. × 16 ft 3 in. (6·17 m × 4·95 m). As in the case of the walls, the principle of cage framework was used, the sections being made up of five squares in width (40 in., 1·02 m). These cages are suspended from the ceiling battens leaving a space of 4½ in. (114 mm) between the wedges and the ceiling (see Fig. 3). To ensure that the wedges do not slip out of the cages, pins were passed through the wedges as shown in Fig. 5. Although no droop existed in the ceiling wedges, stiffening rods were used in these wedges because the extra mass improved the acoustic performance, as mentioned earlier.

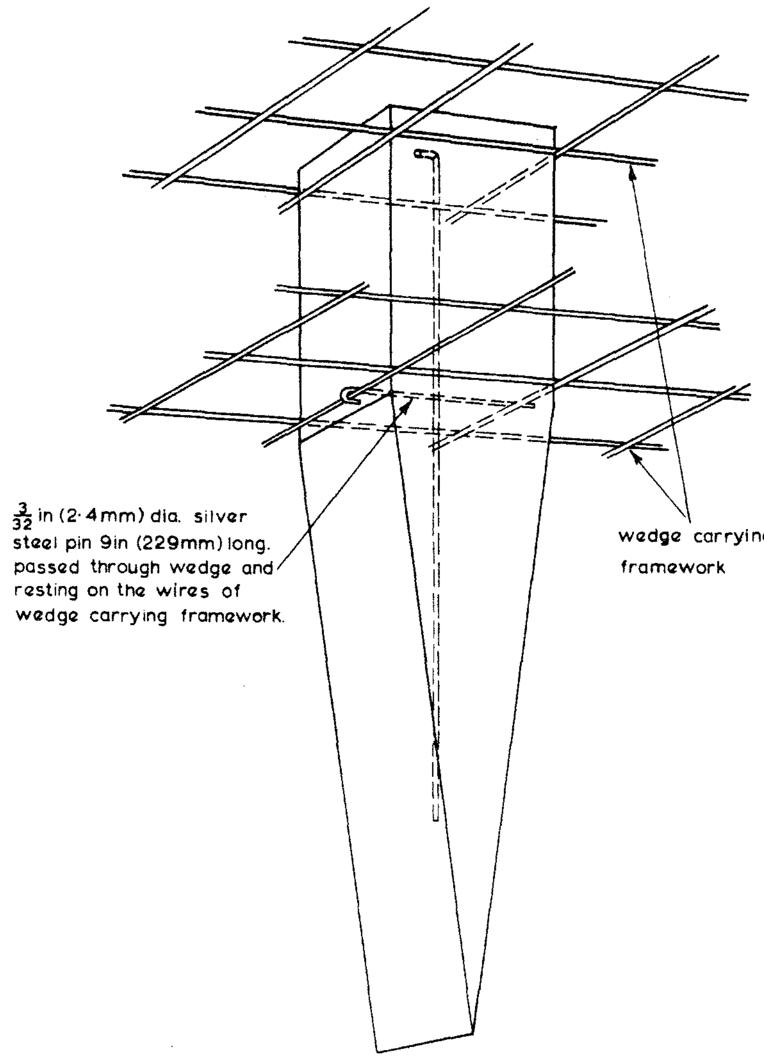


Fig. 5 - Method of retaining ceiling wedges in framework

Where the cages correspond to the holes cast into the ceiling, they were modified by circular apertures incorporated in the normal square mesh. Wedges which come at these points were modified by removing material which would have obscured the holes. This was done by passing a heated wire along the wedge, the wire being

shaped to the contour of the section to be removed. The temperature of the wire was high enough to melt the polyurethane locally, and resulted in a neat cut along the length of the wedge. This apparatus is shown in Fig. 6*.

3.4. Floor Treatment

The floor treatment is basically the same as the walls and ceiling in that wedges are used as the sound-absorbing material. The means of supporting the wedges however had to be considered in conjunction with the design of a separate working floor that would be used in the free field room. Various free field rooms have been constructed throughout the world, and one method of providing a working floor above the wedges is to stretch, permanently, across the room a mesh strong enough to support both those working in the room and any equipment they may need to take in. In some cases the mesh has been of steel, in others of nylon mesh or similar material.

In Research Department, however, it was considered that it should be possible to remove completely any kind of floor. As the mesh floors mentioned above do not allow this, a sectional steel floor was designed which, being made up of small panels, could be easily removed. This principle followed a practice that had been found satisfactory in the existing free field room at Kingswood Warren.

3.4.1. Floor Wedges

As in the case of the ceiling, the wall wedges protrude over part of the floor, leaving an area of 20 ft 3 in. × 16 ft 3 in. (6·17 m × 4·95 m) to be covered by wedges, and requiring a working floor of the same area.

The floor wedges are supported in frameworks similar to those used on the walls and ceilings in such a way that they fit inside the stanchions that support the working floor. The frameworks rest on brackets so that a 4½ in. (114 mm) gap is maintained between the bottom of the wedges and the floor. To stop the wedges gradually sagging, and to provide extra mass, it was realized that some form of stiffening would be needed, but this stiffening could not be such as would present a danger should a person fall into the floor area. The eventual solution was to provide a composite rod as shown in Fig. 7. By inserting springs in the length of the rod, it will bend if a weight falls on to the wedge, but has ample stiffness to remain upright in normal circumstances. Since the wedges would be unsupported at their lower ends, the same principle was used with these wedges as with the ceiling wedges, in that a pin was pushed through them, the protrusions resting on the wires of the wedge cages.

As the assemblers of the floor wedges and frameworks had to work on the concrete floor of the free field room, it was foreseen that difficulties would be experienced in fitting the final wedges. This was overcome by making a special section of four wedges, and lowering this into position from a platform.

3.4.2. Working Floor

To support the working floor, a channel iron foundation grid was made, to which vertical stanchions were welded, each stanchion being nominally 4 ft (1·24 m)

* This apparatus was adopted as the result of a suggestion by members of the Workshops staff.

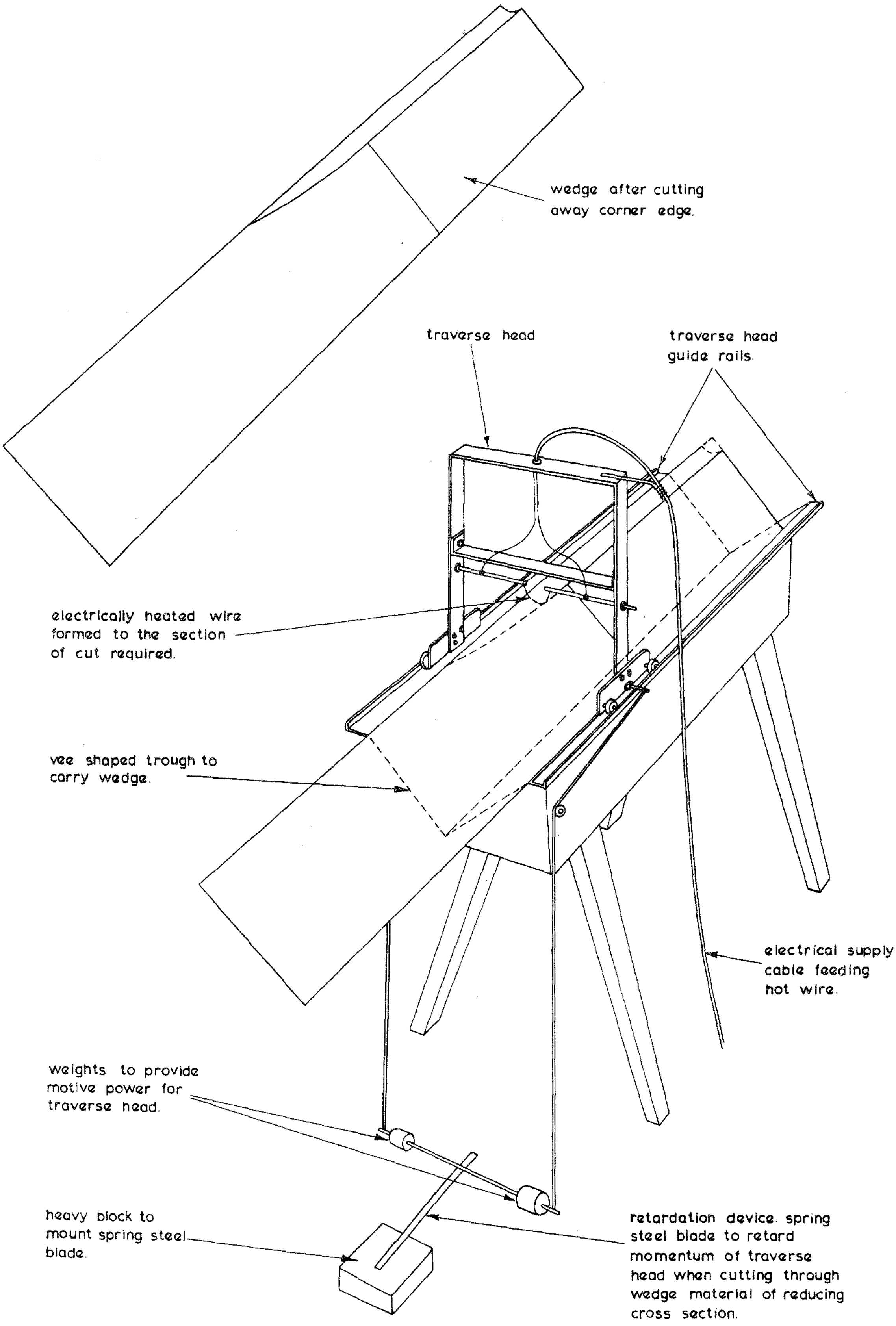


Fig. 6 - Apparatus for cutting section from wedges

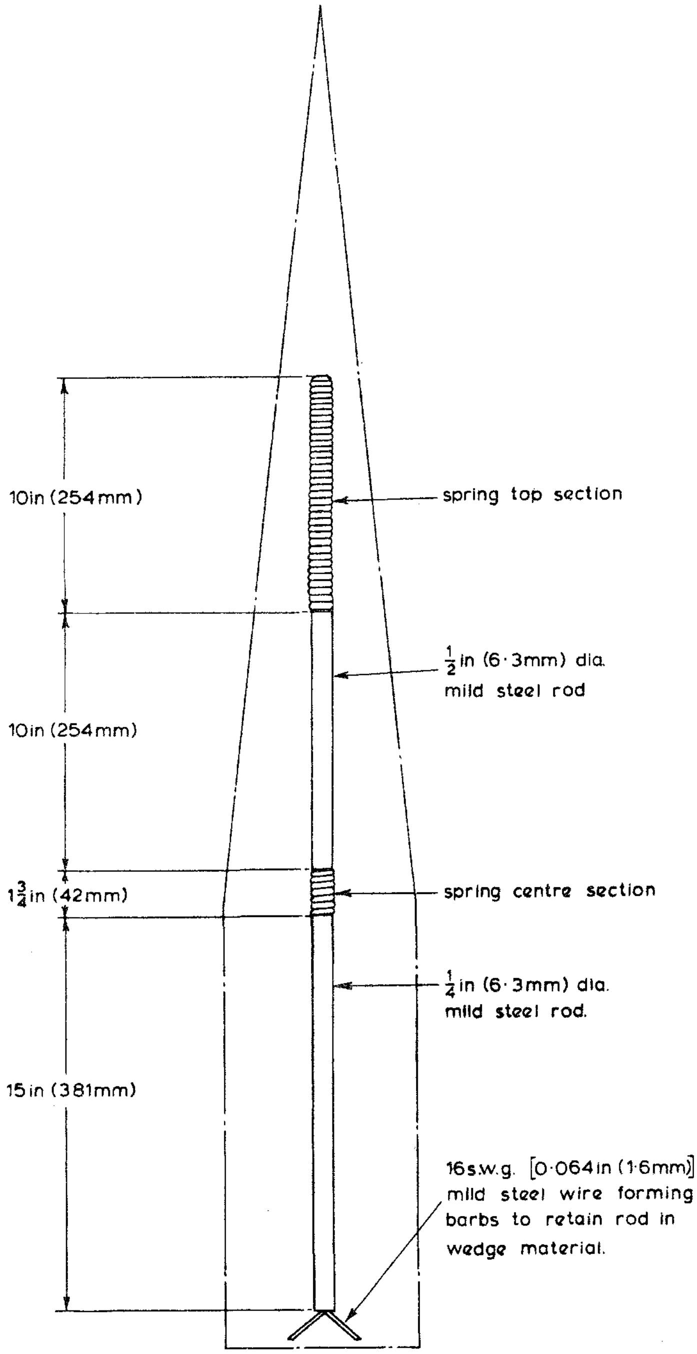


Fig. 7 - Composite rod for use in floor wedges

high from the floor of the free field room. This grid was made up of sections to enable it to be taken into the room after fabrication in the Workshops. Jacking screws are provided for levelling purposes on each section.

The stanchions are slotted at their upper ends and extension pieces can be slipped into place to make the total height above floor level 6 ft 2 in. (1·88 m). Each extension piece has a small platform at its upper end, drilled to provide location

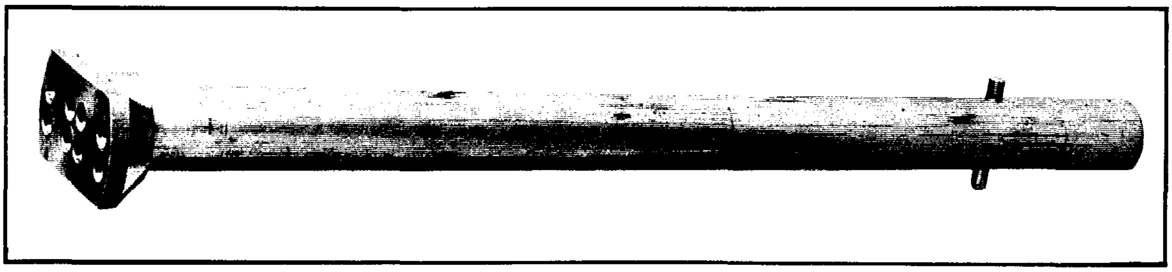


Fig. 8 - Stanchion extension and platform

holes for removable panels that make up the working floor. Fig. 8 shows an extension piece and platform, and Fig. 9 shows a view of the free field room with the working floor in position.

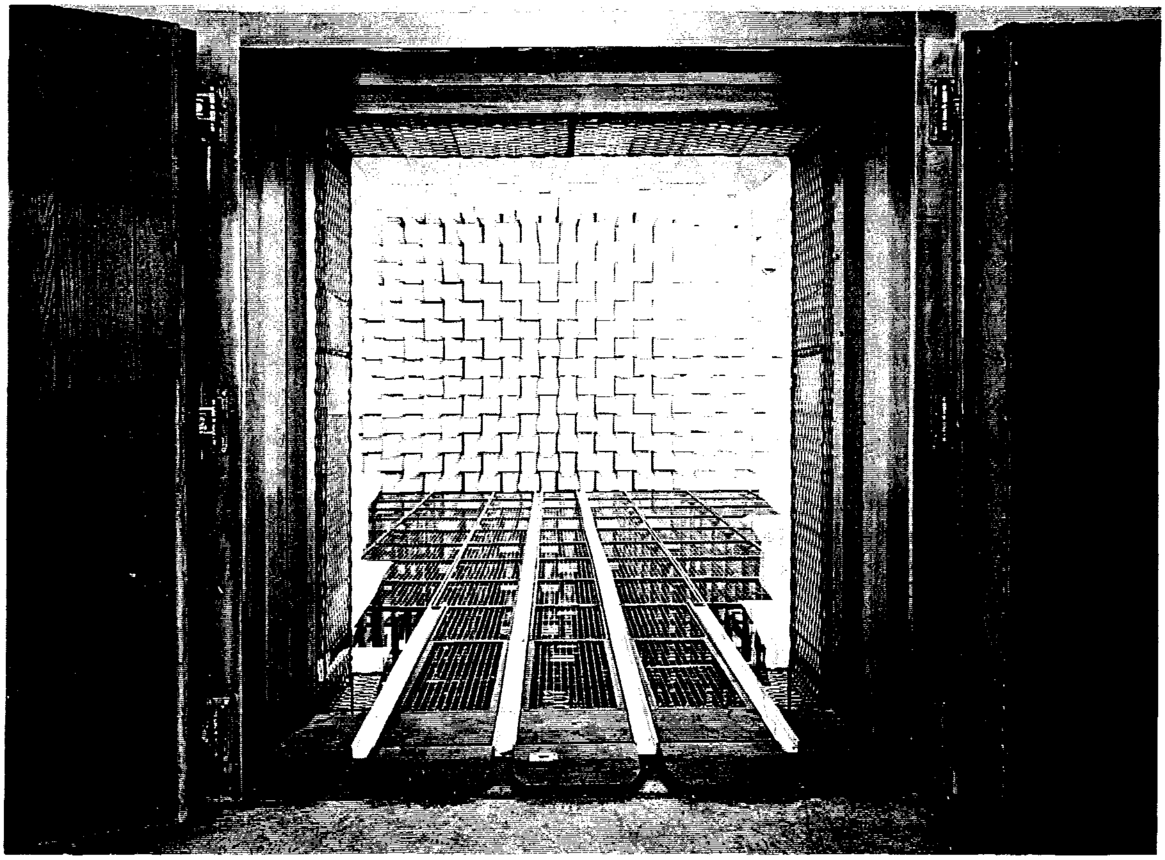


Fig. 9 - View of free field sound measurement room showing working floor, rails and door aperture details

The working floor is made of panels, each panel being a light frame of 1 in. × ½ in. angle (25·4 mm × 12·7 mm) into which is welded a 3/16 in. (5 mm) diameter wire mesh with a spacing of 2 in. × 1 in. (51 mm × 25·4 mm). These panels have a small peg in each corner which correspond with the holes in the platform on the extensions to the stanchions. The panels are coated with nylon to eliminate the possibility of steel splinters breaking away.

Removable rails in the form of channels are provided at 16 in. (406 mm) centres to facilitate a trolley being wheeled into the room, and to support the removable wedge trollies forming the acoustic treatment of the doorway area (see Section 4). These rails, which are shown in Fig. 9, are carried on the small platforms of the stanchion extensions and are located in position by the holes in those platforms. It will be seen from Fig. 9, that the rails can be extended right across the room or just taken for a short distance beyond the threshold of the doorway. To complete the floor between the rails, small floor panels are available. With the exception of the 16 in. (406 mm) spacing between the rails, the whole of the working floor structure and panel arrangement is based on a 24 in. × 24 in. (610 mm × 610 mm) module.

The height of the working floor above the bottom of the free field room was chosen so that the centre of the working space of the free field room would be 4 ft (1·24 m) above the floor.

Normally, apparatus under test would be placed at the centre of the working space. For setting up and adjustment purposes, this makes a comfortable working height for a person dealing with such apparatus.

To lay the floor, assuming there are no floor panels in position, the extensions to the stanchions near to the entrance to the room would first be fitted into place, then floor panels put down. From these panels further stanchion extensions can be added and more panels put down, and so on.

This design enables a floor to be laid either over the whole or partial area. For optimum conditions of test, the whole floor and all the extensions to the stanchions can be removed, leaving only the tops of the stanchions visible, and these are fitted with protective caps as shown in Fig. 10. These caps provide a safety measure against harm to staff, should they fall from the working floor.

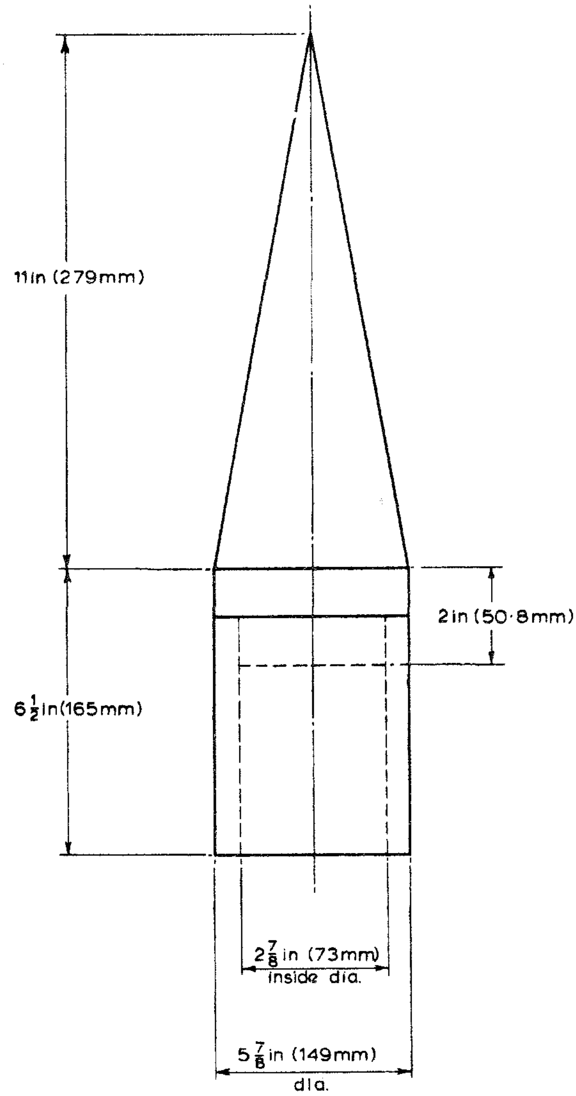


Fig. 10 - Protective cap for stanchion

To complete the design of the floor arrangement, handrails have been provided which can be slipped into position in the extension pieces to the stanchion. These are used whenever the working floor is laid, to prevent staff from accidentally falling from the floor (see Fig. 11).

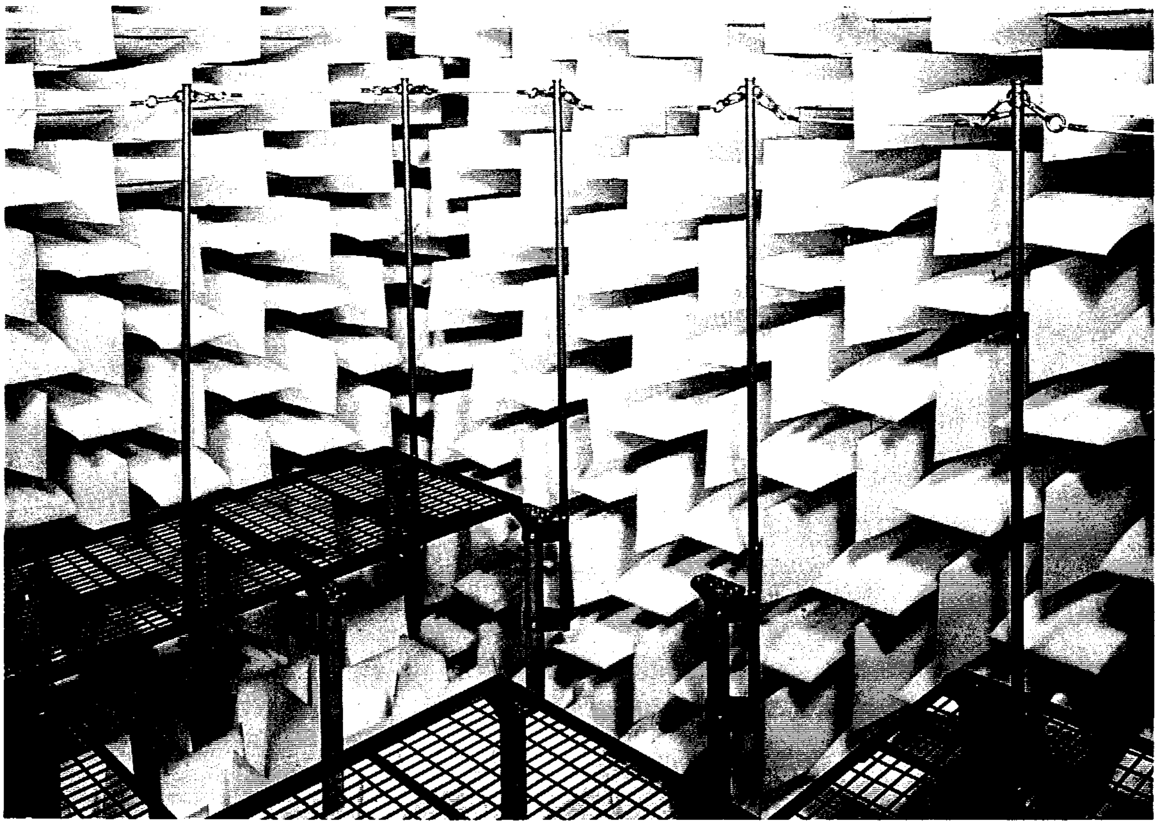


Fig. 11 - Details of handrails

3.5. Erection Sequence of Internal Treatment

Having described the wedge structure of the free field room, it should be explained why the walls were completely covered before completing the ceiling and floor. Apart from the obvious advantage of keeping the suspended weight on the ceiling to a minimum, there is the added advantage of erecting as described in that the amount of work to be carried out overhead is considerably reduced. But there is also an important acoustical reason which is shown diagrammatically in Fig. 12. The figure represents a cross section, in elevation, of the room. In Fig. 12(*a*) the wedge banks are shown as erected. Fig. 12(*b*) shows the formation if the ceiling and floor were to have all their wedges completed before the walls. There are acoustic paths between the wedge banks, and it is important to arrange these paths so that 'θ' is as near to 90° as possible. Thus assuming the sound source to be in the centre of the room, the arrangement shown in Fig. 12(*a*) will be the better choice.

4. DOORS TO THE FREE FIELD SOUND MEASUREMENT ROOM

The doors to the free field room close an aperture of 6 ft 2 in. high × 5 ft 4 in. wide (1·88 m × 1·6 m). They are of heavy construction, and the weight involved was one of the reasons for choosing two doors rather than one. Each door is

6¾ in. thick (172 mm), and Fig. 13 shows some of the details of the construction. To give good sealing properties between the doors and frame, the left-hand door, which is the first to be closed, has ½ in. (12·7 mm) of felt on all edges, and the right-hand door has felt on the top, bottom, and hinge side. This arrangement can be seen in Fig. 9.

The existing smaller free field room had the wedges as an integral part of the door; this had proved to be cumbersome. The idea of having two doors in the new room would have also presented additional wedge design problems if the old method were to be used. Consideration was given to alternative door wedge arrangements, and this resulted in the decision to provide two trollies, independent of the doors, each trolley carrying a wedge assembly to close the door aperture. One of these trollies is shown in Fig. 14, and in Fig. 15 one of the trollies can be seen in position inside the free field room.

These trollies run on the rails shown in Figs. 9 and 15 and are guided to the rails by grooves cut into the threshold of the doorway. Adequate lead into these grooves is provided and to seal these grooves, felt pads are added to the bottom of each door.

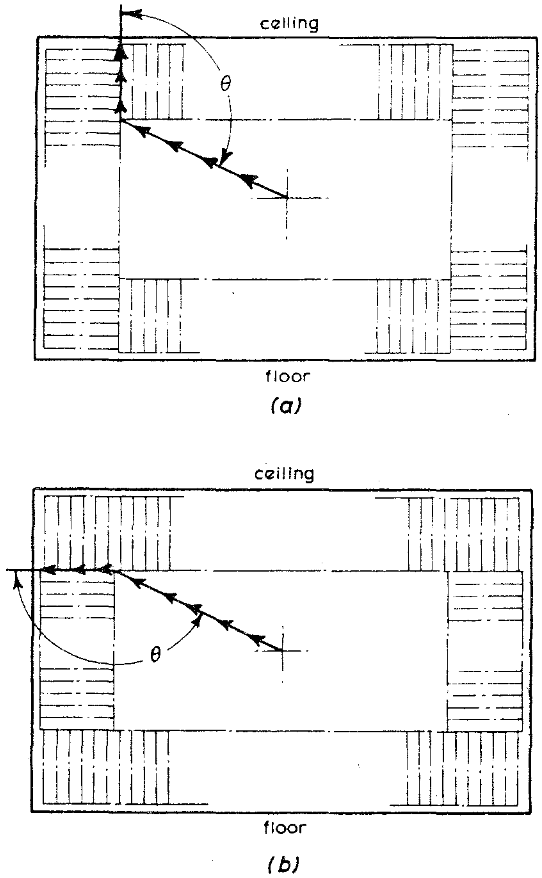


Fig. 12 - Cross section in elevation of free field sound measurement room

(a) Treatment with walls completed before ceiling and floor
(b) Treatment with ceiling and floor completed before walls

In operation these trollies are wheeled into the free field room before the doors are closed, a register being provided on the rails to give the trollies a correct location in the room relative to the other wedges. The doors can be opened from the inside by pushing a bolt, which protrudes into the room on the right-hand door. When the wedge trollies are in position, this bolt cannot be reached, but the right-hand trolley and the bolt have been designed so that if the trolley is pushed against the bolt, this will cause the door to open. The trolley can then be pushed clear of the room.

Whilst the wedge trollies take up floor space when in the apparatus room, they are manoeuverable and can therefore be placed in the least inconvenient position, whereas wedges mounted on the doors would always be a nuisance.

5. ROTATING SHAFT AND ACTUATING MECHANISM

In discussing the general building details, reference was made to a shaft which entered the free field room through a hole in the ceiling and to the mechanism

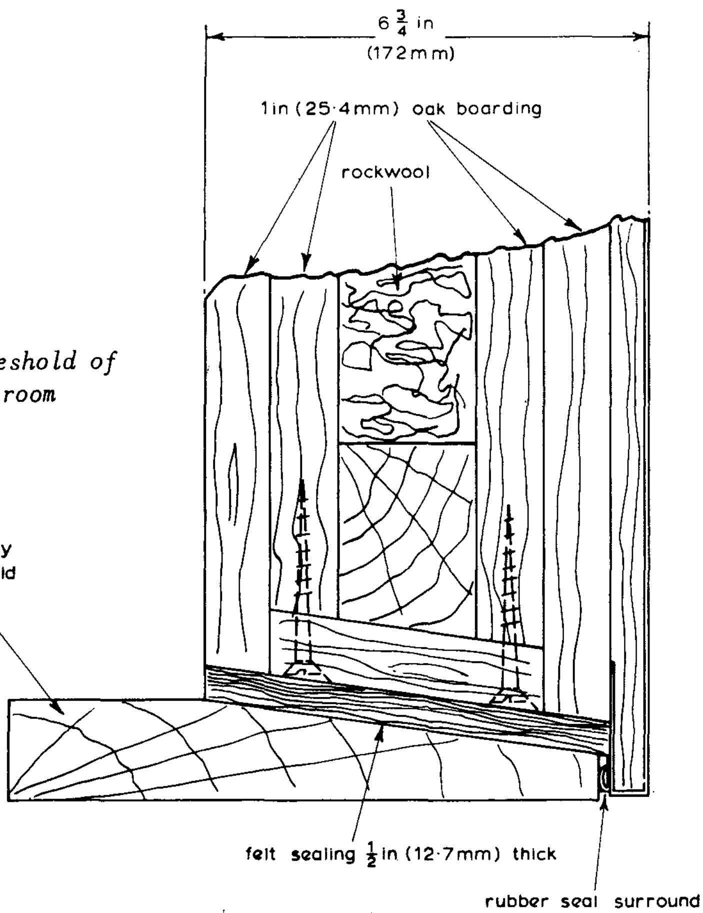


Fig. 13 - Details of door and threshold of free field sound measurement room

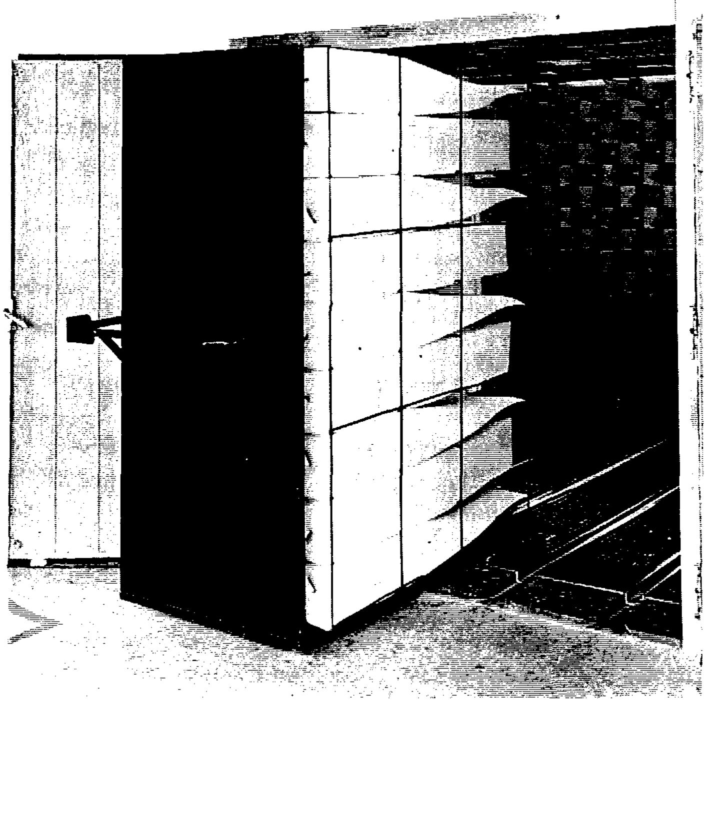


Fig. 14 - Wedge trolley

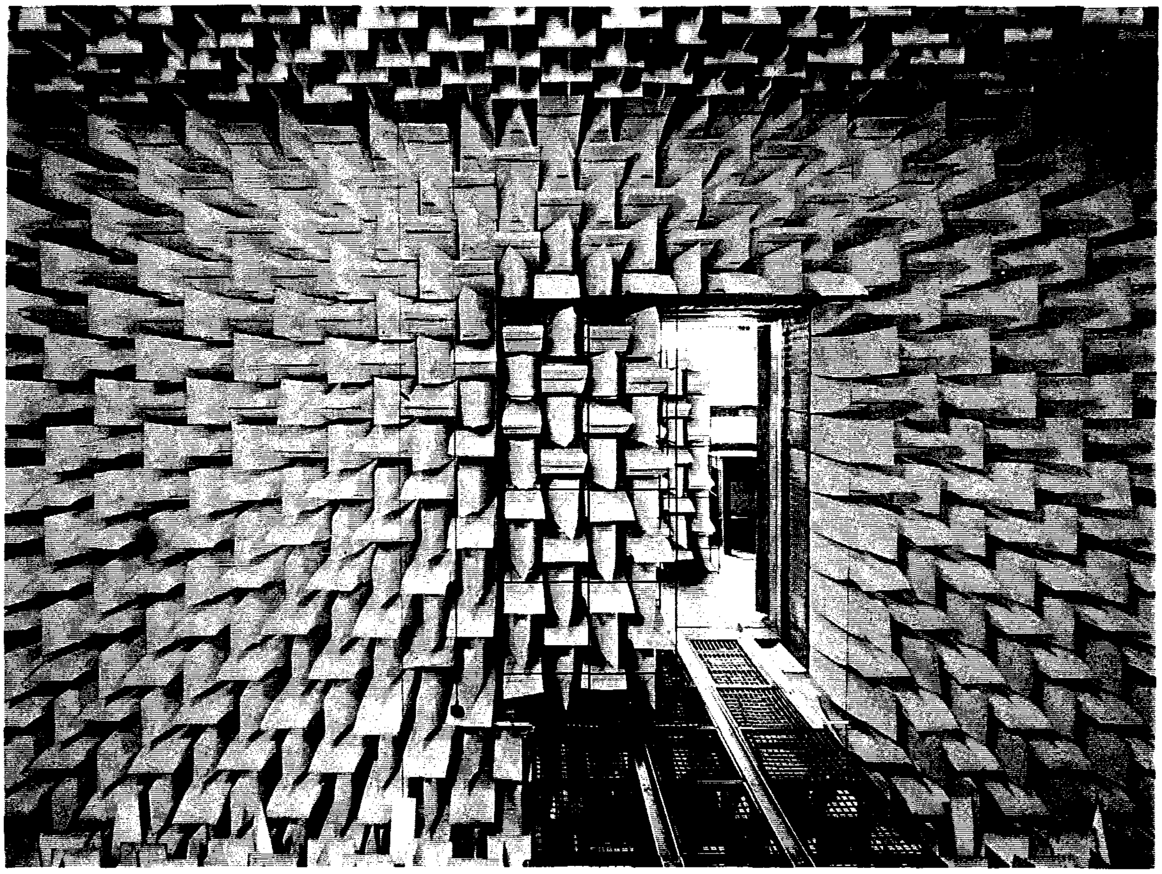


Fig. 15 - View of south wall showing doorway to apparatus room and wedge treatment

for driving this shaft. Fig. 16 is a more detailed sketch of the design, which is based on that of the earlier free field room.* The mechanism imparts both rotary and vertical motion to the shaft.

Equipment undergoing tests, such as microphones or loudspeakers, can be suspended from the shaft and rotated through 380° in order to determine their directional characteristics. The extra 20° over 360° is provided to enable an overlap to be obtained of the experimental readings at the beginning and end of the rotation.

The shaft can be moved vertically so that the bottom end is only a few inches below the tips of the ceiling wedges, or down to 3 ft 6 in. (1·07 m) below the tips of these wedges. Extension pieces can be added to the shaft if necessary. The vertical motion is needed to enable accurate positioning relative to the centre of the room whatever may be the dimensions of the item under test.

A horizontal boom can be fitted to the end of the shaft to enable small apparatus or measuring instruments to be rotated about the axis of the shaft. In finding the directional characteristics of very heavy equipment, it may be necessary to place the latter in the centre of the free field room, and move the measuring

* Mr. J.R. Chew (Electro-Acoustics Group) and Mr. B.D. O'Connor (Drawing Office) were mainly responsible for the design of the shaft actuating mechanism.

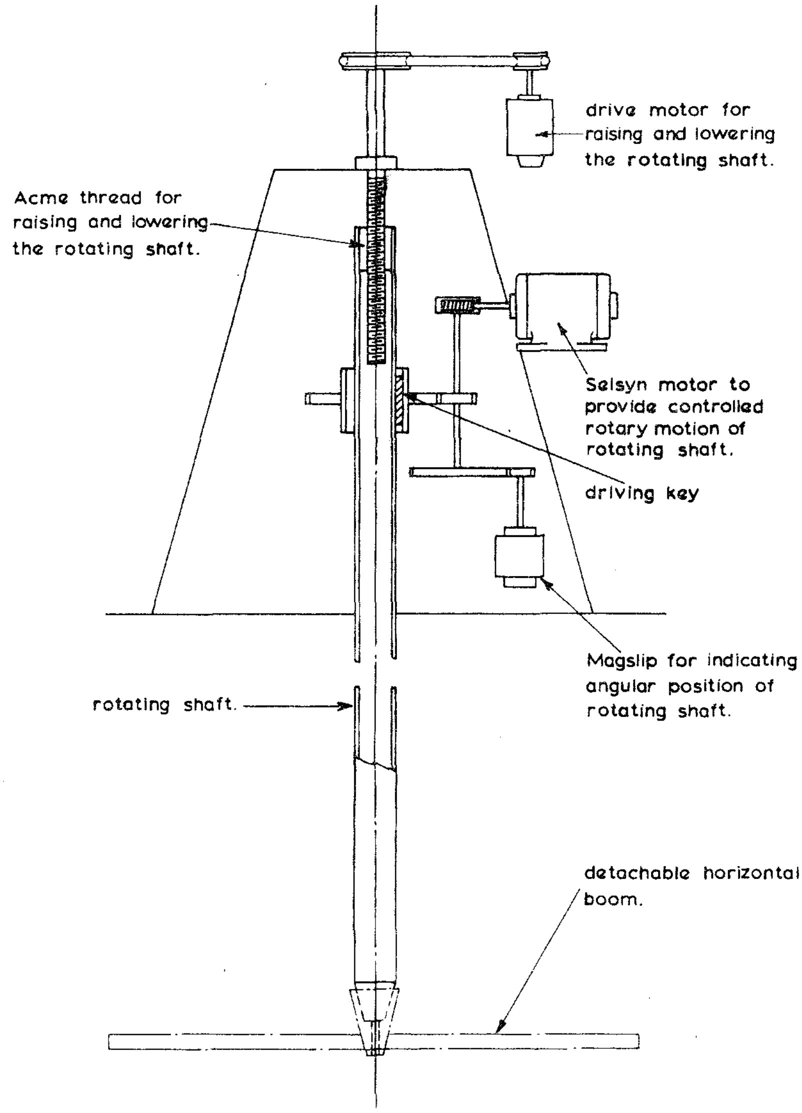


Fig. 16 - Principle of rotating shaft and actuating mechanism

instruments around the equipment undergoing test. The length of the boom is normally 6 ft (1·83 m) but extension pieces are available.

The actuating mechanism which drives the shaft both in rotary and vertical motion is in the attic space. The rotating motion is supplied by a Selsyn motor through gears designed to eliminate backlash. This motor is controlled from the apparatus room, with indication of the angular position of the shaft being given by a Magslip feeding back information to the control point in the apparatus room. The vertical travel of the shaft is controlled by a simple change-over switch in the free field room.

Electro-magnetic braking is used on the vertical driving mechanism to ensure that good repeat readings are obtained when setting the shaft in the vertical sense.

It will be noted that the rotary control is in the apparatus room, and the vertical control in the free field room. This arrangement was chosen since normally

the vertical setting up of apparatus or of the boom on the shaft would be done by staff working in the room. Once this setting is achieved rotary motion would be controlled from the apparatus room whilst the actual test was in hand, and of course with the doors to the free field room closed.

It will be seen from Fig. 1 that the actuating mechanism is mounted on the main ceiling beams, and normally the shaft protrudes into the free field room through a hole which is central to that room. Nevertheless, the whole mechanism can, if necessary, be moved along the ceiling beams to enable the shaft to enter the free field room through the other holes referred to in Section 2.

6. SERVICES OF THE FREE FIELD SOUND MEASUREMENT ROOM

The new room has needed special consideration in the provision of lighting, heating, and technical electrical services, as well as for the provision of technical wiring.

6.1. Lighting

Nine specially made fittings are used; these have been designed to provide the main lighting, since the acoustic performance of the room could be seriously affected by conventional lighting fittings. The fittings are shown in Fig. 17, and are designed so that they can accommodate a 100 W G.L.S. lamp, and can be passed from the attic space, through the tubes in the ceiling. The cables feeding the lamps are led away from the top of the fitting assemblies to outlet sockets, placed close to the tubes. For relamping and maintenance, the fittings are withdrawn into the attic space, thus providing a safety factor by removing any need for maintenance in the free field room.

Built into two of the special light fittings are emergency lamps, which light up automatically in case of failure of the electricity supply mains. The emergency lamps, two in each fitting, are 3·5 V, 1 A Krypton lamps, and derive their power from nickel-iron batteries. A relay placed between the lamps and the batteries remains open as long as the mains electricity is available but failure of this supply allows the relay to close and the lamps to be energized. The batteries chosen need no maintenance for many years, and are automatically maintained in a fully charged condition by a mains fed rectifier.

6.2. Heating

Various types of heating were considered for the free field room, including radiant heat, hot water and portable electric units. Of those mentioned, the first had the disadvantages of a possible fire hazard, being a very hot source, coupled with the objection to a source of heat having to be placed inside the room where it would constitute an acoustic reflecting surface. Hot water heating had installation difficulties coupled with the same acoustic objections and portable units had obvious nuisance value, especially when the room is shut for experiments.

The final choice was to use electric heating tapes, specially fitted to local design. The principle chosen was to avoid a few local heat sources and make

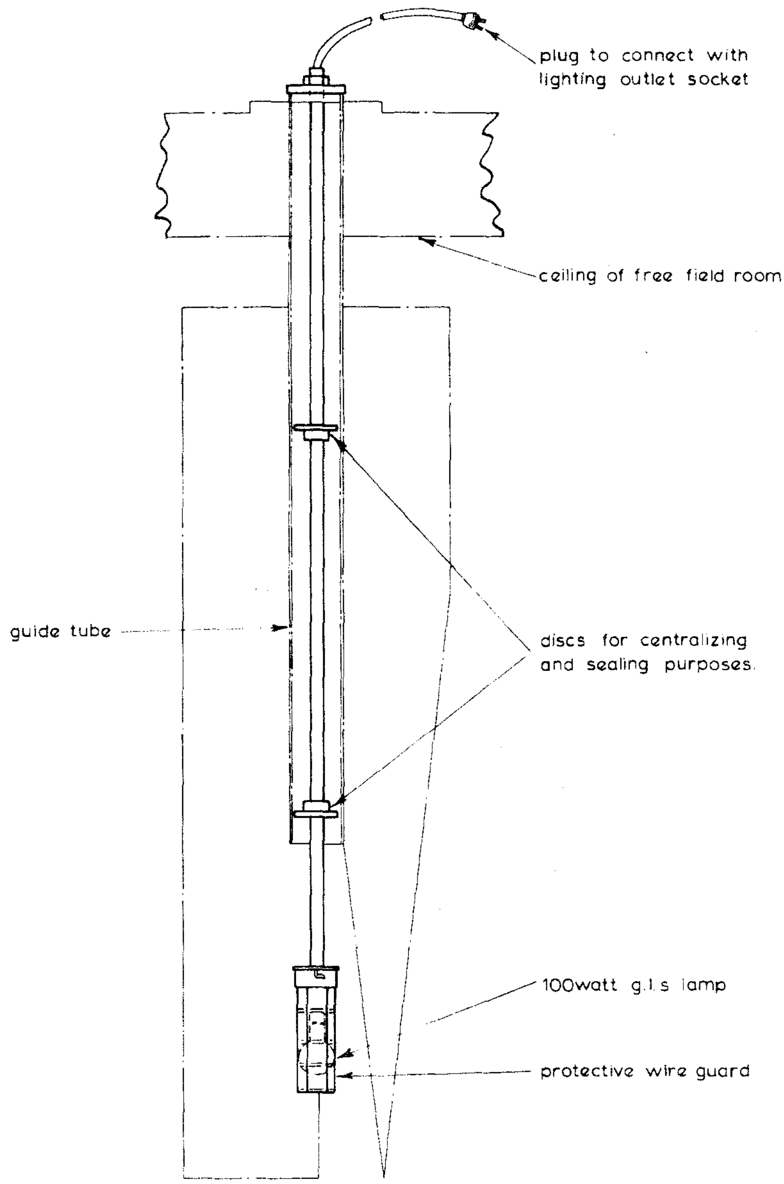


Fig. 17 - Special lighting fitting

seventy-eight small heater units as shown in Fig. 18. These were mounted on the fixed portions of the stanchions and, where necessary, the surrounding wedges were modified so as to be adequately clear of the heater unit. The heating tape, whose rating is 5 W per ft (305 mm) at 240 V, is wound on to the perforated metal cylinder, the tape length being such that the dissipation is 50 W per heater at 240 V. For maintenance purposes, the whole unit can be lifted off the stanchion from the level of the removable floor, each unit being provided with a plug and socket electrical connexion. The heater units have a split collar at the top which securely clamps on the stanchion, so that no vibrations are set up during experiments.

Before choosing the tapes, two major factors had to be considered; first the heating requirement of the room, and secondly the permissible surface temperature

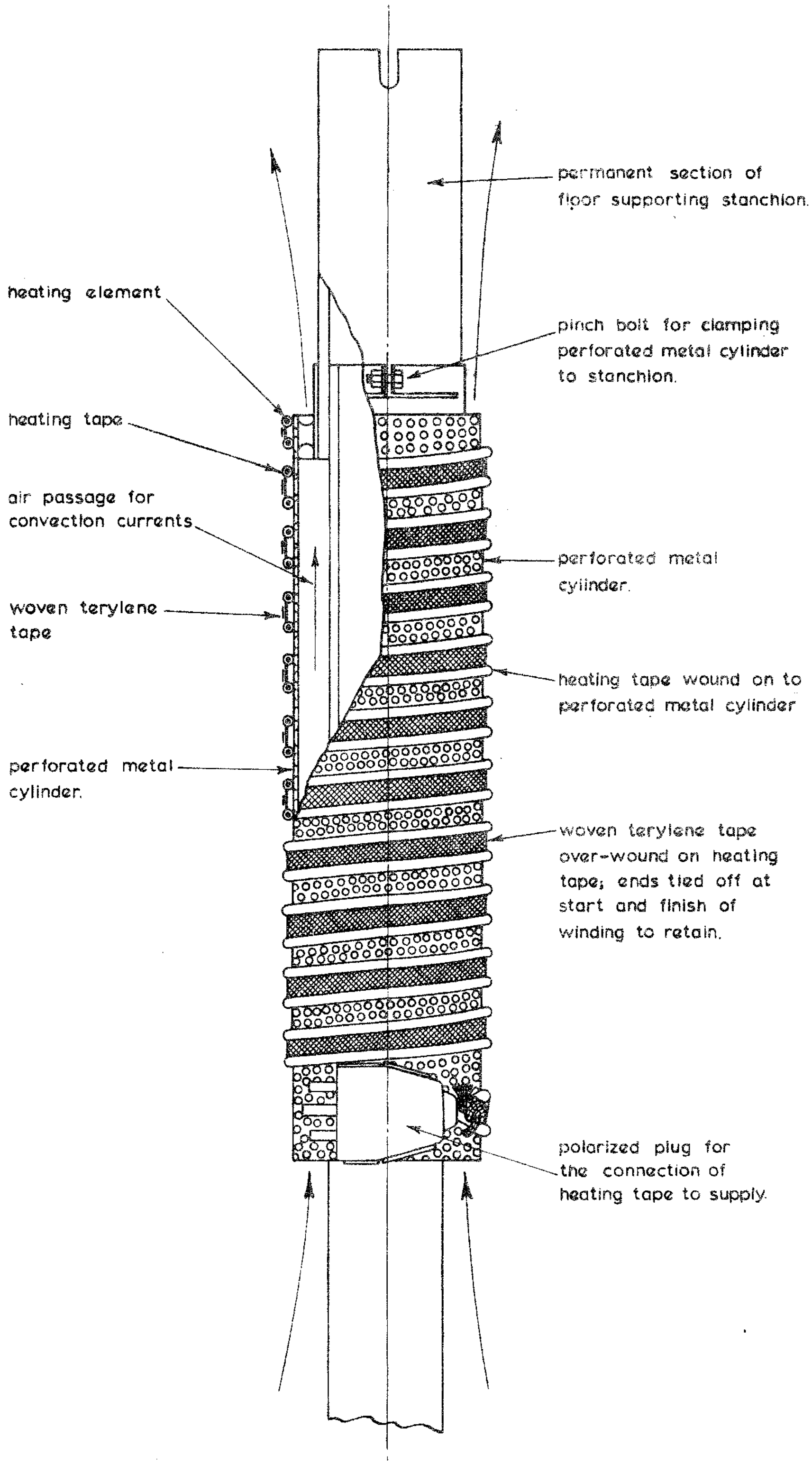


Fig. 18 - Heating unit

of the heating elements. Since the room consists of an insulated windowless box inside the main structure, with only the door aperture through which heat can easily escape, and as the ceiling has another room over the top, it was assessed that once the room was up to a working temperature, variations would be fairly small. A further contributory factor would be the conventional electrical heating of the attic space, and the other adjacent rooms which would help to keep the whole building warm. With this knowledge, calculations indicated that 3 kW should provide the maximum heating required. The heating units were grouped in two banks, one to the left of the doorway, and the other to the right, each bank having a thermostat to control it, thermostats being about 12 in. (305 mm) above the tops of the floor wedges. No heating elements were placed in the central area of the floor, since convection currents due to heat may disturb apparatus under test.

Because the heating units are surrounded by floor wedges, it was necessary to carry out experiments to ensure that the maximum permissible surface working temperature of 156°F (69°C) for these tapes was not exceeded. The working conditions selected were a 200 V supply giving a tape surface temperature of the order of 120°F (48·8°C) and a total heat dissipation of 2·8 kW.

The supply to the heaters is by means of mineral insulated cable (M.I.C.) from two distribution boxes on the floor. The M.I.C. is run to junction boxes placed at the foot of the stanchions. The choice of M.I.C. was based on the desire for long life free of maintenance problems, coupled with the minimum of fire risk.

7. ELECTRICAL SERVICES AND SIGNAL LINES

The services dealt with under this heading are those to the free field room, and cover normal mains electricity, stabilized supply, control lines for the boom actuating mechanism and signal lines. These services are illustrated in the schematic diagram Fig. 19 and it will be seen from this diagram that all the services are linked with either the apparatus room or attic space, and some of the services also connect with the main laboratories. The focal point for these services is a bay in the apparatus room.

A feature of this bay is that it is mounted on rollers. This enables the bay to be located close to the wall when in normal use but it can easily be pulled forward to enable staff to get behind it for maintenance or modifications. By this method, floor space is better utilized since a fixed bay would need to be clear of the wall at all times, to allow access to the back when needed.

7.1. Main Electrical Supply

The only normal mains supply available in the free field room terminates in a 15 A outlet socket, this socket being mounted on a stanchion, and placed 18 in. (457 mm) below the tops of the floor wedges. This supply is intended to serve a general need should occasion arise for normal electrical power. Mains outlets are available in all the other rooms of the building.

Experimental requirements, however, necessitate the provision of stabilized power supplies at mains voltage, both in the free field room and at the control bay

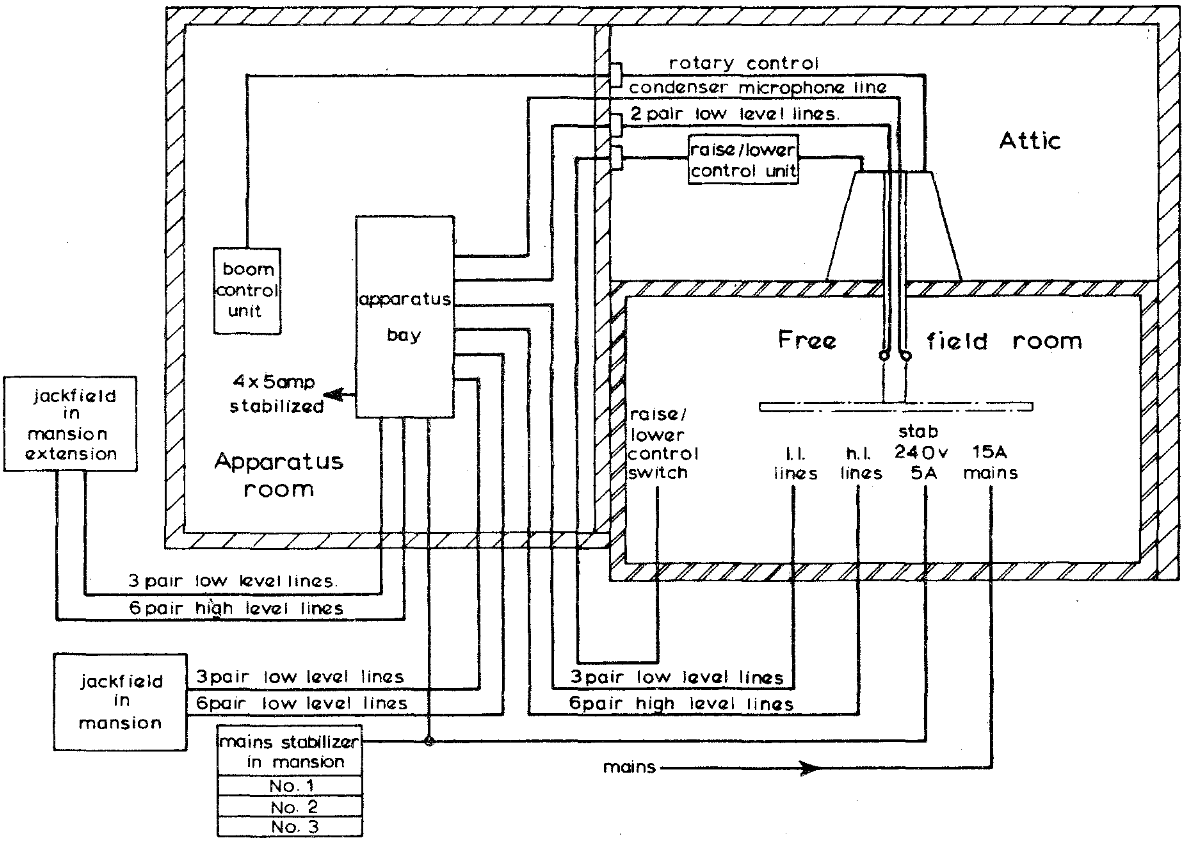


Fig. 19 - Schematic of technical electrical services and signal lines

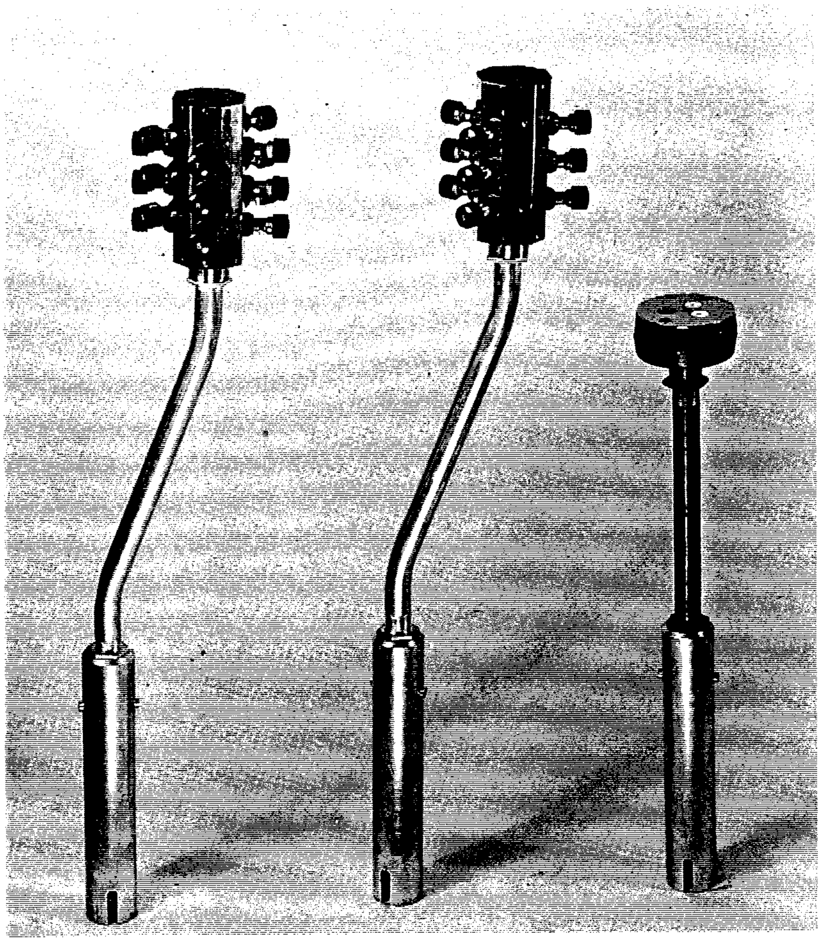
in the apparatus room. All the permanent equipment in the control bay is fed by stabilized power. The 5 A outlet socket in the free field room is placed near the centre of the room, just below the tops of the floor wedges. The stabilizers providing this power are provided with time switches to enable them to be switched on and off automatically, and also have an alarm system which operates should the output voltage wander outside the prescribed limits.

7.2. Signal Lines

Permanent signal lines have been provided between the bay in the apparatus room and the free field room, and also to the main laboratories. High-level and low-level lines are installed, the former being lines taking signals of about 1 V, (used for tone sources, amplifiers) and the latter for signals of the order of 1 mV, (almost exclusively for microphones). The termination of the lines in both the bay in the apparatus room and in other laboratories, is at jackfields. The high-level lines are of ten-pair cable with the conductors of single copper wire 0·020 in. diameter (0·5 mm), the pairs being screened, and the whole cable P.V.C. sheathed. The low-level lines are of five pairs only.

The terminations of these lines in the free field room are to modified female halves of Cannon connectors type EP12-1C, and EP15-1C. These are mounted on the stanchion structure, being placed about 10 in. (254 mm) below the tips of the wedges.

To connect with the female halves, extension pieces have been provided, one end of these extensions having a male connector and the other end a terminal block. Both the extension piece and the termination arrangement are shown in Fig. 20. The terminals of the block of the extension are labelled T, R, and S to indicate the tip and ring of the jackfield sockets at the other end of the lines, as well as the screen of the particular pair connected to them.



(a) (b) (c)

Fig. 20 - Extension pieces for electrical services

(a) and *(b)* Termination for signal lines *(c)* Termination for 5 A stablized supply

The main reason for adopting this termination design in the free field room is that whilst normally the terminal blocks standing above the tops of the floor wedges by about 6 in. (152 mm) does not seriously interfere with the acoustic properties of the room, there would be occasions when this could not be tolerated. In such instances, the extension pieces can be removed, leaving the exposed fixed female portion well down in the wedges. A similar design has also been used for the 5 A outlet socket of the stabilized power supply.

To complete the low-level signal line arrangement, two further pairs are carried from the control bay to the attic space and then passed down the column

of the boom actuating mechanism terminating at the base of the column. A condenser microphone line also runs from the bay to the base of the column.

7.3. Safety Measures

Two built in 'safety measures' have been provided. The first is a heat detector, placed in the ceiling wedges in a similar manner to the lighting fittings. The device will cause an alarm bell to ring should excessive heat be generated in the room, as would be the case if there were a fire.

The second is a small microphone, linked to a loudspeaker in the main laboratories and adjacent apparatus rooms. Should anyone be trapped in the room or meet with a mishap, it is therefore possible for them to draw the attention of other people to their difficulties.

8. CONCLUSIONS

The ultimate test of the efficiency of the free field room is of course in its acoustic properties and these are dealt with in the appropriate report.[2]

The innovations such as the door arrangement, the working floor, the method of heating the free field room, and the mounting of the control bays on rollers have all proved very satisfactory.

9. REFERENCES

1. 'The Design of a New Free-Field Sound Measurement Room: The Selection of Sound Absorbent Material', Research Department Report No. L-055, Serial No. 1964/42.
2. 'The Design of a New Free-Field Sound Measurement Room: Specification and Performance', Research Department Report No. L-060, Serial No. 1965/17.

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